Miniature Multichannel Fiber-Optic Signal Conditioner

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High-fidelity testing requires miniature, minimally invasive sensors and readout systems to go inside test assemblies. Sensors also need to be optically read out to reduce exposure of sensitive components to electrical energy. Several different sensors are being built to measure parameters such as acceleration, strain, displacement, pressure, and temperature, at various locations within test assemblies. A variety of commercial and custom-made Fabry-Perot interferometric sensors are available, but these signal conditioners (readout systems) are big and bulky, usually rack mounted, and unacceptable for LLNL applications.

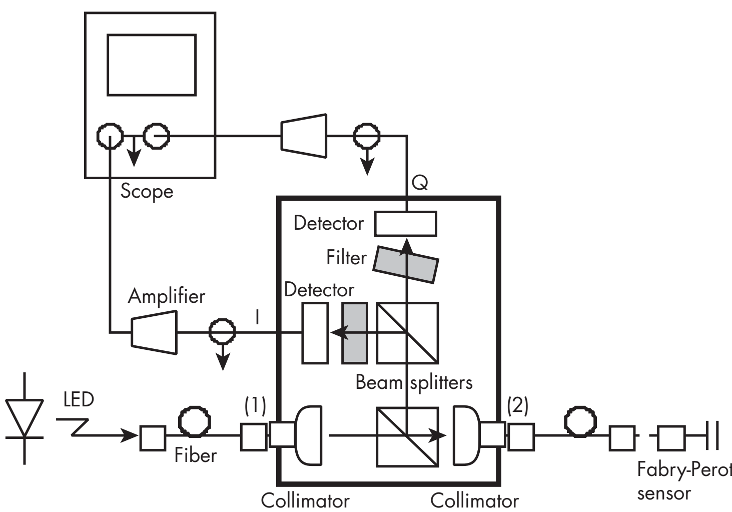

Figure 1. Schematic diagram of basic components for I/Q signal analysis.

Project Goals

This was the second and final year of a project with two main goals: 1) finish implementing a miniature three-channel fiber-optic readout conditioner; and 2) begin reduction to practice of technology for a miniature absolute conditioner for applications where absolute measurements are necessary. We completed our first goal and made significant progress on the second.

Relevance to LLNL Mission

High-fidelity flight tests are required by the weapons stockpile stewardship mission to ensure weapon viability without underground testing.

FY2004 Accomplishments and Results

The I/Q Concept. For relative measurements we chose the in-phase and quadrature I/Q technique, which takes advantage of the virtually sinusoidal shape of interference fringes that result from fiber-optic sensors. Figure 1 is a schematic of the main components. A phase-modulated light beam is reflected from a Fabry-Perot sensor split and directed to two filters, which look at a narrow portion of the spectrum (about 10 nm wide), making fringes visible as an amplitude modulation. One filter produces the in-phase signal. The second filter is tuned to a slightly different part of the spectrum and produces a fringe pattern that is 90° out of phase (in quadrature). As the Fabry-Perot sensor changes dimension due to a physical stimulus, the corresponding change in the phase angle allows reconstructing the temporal behavior of the phenomenon being measured.

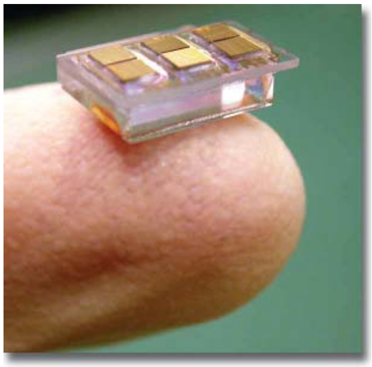

Figure 2. Optical elements on a human finger.

Filament—1mm diameter

Figure 3. Miniature filament light source for coupling to optical fiber.

I/Q Implementation. The optical path can be implemented entirely within a small slab of glass (3 mm wide ¥ 2 mm thick ¥ 10 mm long). Additional channels are allowed by increasing the width of the glass and adding detectors in parallel. Figure 2 is a photo of the complete three-channel optical element sitting on a human finger. It includes all the components described above except the collimators. State-of-the-art technologies were used for nanostructured thin film filters, chip detectors and flip-chip mounting and connection.

To test operation, we mounted a Fabry-Perot accelerometer on a shaker table and recorded the signal using our conditioner, an external oscilloscope, and a computer.

Absolute Conditioner. We have been exploring techniques for miniaturization of absolute signal conditioning. We built a laboratory bench system that uses a light bulb as a source and a piezoelectrically-tuned filter to perform the signal capture transform. We are also collaborating with NASA to implement a miniature incandescent filament light source. LLNL made key contributions to packaging and hermetic sealing. A photo of one of our devices is shown operating in Fig. 3. With NASA, we are preparing to transfer this technology to the commercial sector.

Related References

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2. Lo, Y., J. S. Sirkis, and C. Chang, "Passive Signal Processing of In-Line Fiber Etalon Sensors for High Strain-Rate Loading," *Journal of Lightwave Technology*, **15**, (8), August 1997.
3. Schmidt, M., and N. Furstenau, "Fiber-Optic Extrinsic Fabry-Perot Interferometer Sensors with Three-Wavelength Digital Phase Demodulation," *Optics Letters*, **24**, (9), May 1, 1999.
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FY2005 Proposed Work

Seventy percent of the volume of our current three-channel conditioner comprises commercial collimators. By customizing, we can reduce the volume of the collimators by a factor of two or more. Additionally, we would like to include the electronics for amplifying, digitizing, and multiplexing the analog signals on a programmable logic chip incorporated into our package. Finally, we need to miniaturize and implement an absolute measurement conditioner.